## Author Response: Gravity Affects Lens Position During Accommodation

In referring to our study,[1] Schachar[2] writes in the first paragraph of his letter "They concluded that the reduction in anterior chamber depth in the prone position during high levels of accommodation slackens the zonules sufficiently to allow the lens to move under the effect of gravity." We made no such conclusion. Our conclusion was that slackening of zonules during high levels of accommodation in the prone position allows the lens to move under the effect of gravity. We assume that this is what Schachar meant.

Schachar decides that a no-drug/minimum accommodation difference in anterior chamber depth between upright and downward head positions should be the baseline condition in our study to which other results should be compared. In his opinion, combining this comparison with measurement variability indicates that the effects we found are not real.

Schachar's analysis in his third paragraph has a basic flaw. If there is a baseline condition, it would be the anterior chamber depth in the upright position for the no-drug/minimum accommodation combination, not the difference in anterior chamber depths between downwards and upright head positions for this combination. The other combination differences between downwards and upright head positions should be compared to zero, not by how much they vary from the no-drug/minimum accommodation combination difference. This gives significant mean effects of gravity for the young participants of 0.04 to 0.07 mm and for older participants of 0.08 to 0.12 mm (our Fig. 3C). Schachar writes that effects for drug conditions probably reflect drug-induced smaller pupil size; leaving aside that this claim is based on a study that dilated rather than constricted pupils,[3] this is irrelevant as comparisons should be made within, not between, drug conditions.

A second issue is Schachar's assertion that the no-drug/minimum accommodation combination difference in anterior chamber depths between downwards and upright head positions should have been greater for the older than for the young participants, rather than the opposite as we found. His basis for this is that older lenses have greater diameters in the unaccommodated state (giving reduced tension of the zonules) and greater weights than young lenses, making older lenses more susceptible to the effects of gravity. Some,[4–6] although not all,[7] studies of lens diameter indicates that it does not change with age in the unaccommodated state; Schachar's increase in diameter from 8.8 (young) to 9.5 (older) mm lenses comes from his own study of excised lenses[8] and is irrelevant for his argument. The increasing weight of the lens with ageing may have been a contributing factor to a greater effect of gravity on anterior chamber depth for the older than for the young participants when pilocarpine was used.

A third issue is that of measurement variability, which Schachar claims to explain some of our differences. He cites two papers concerning repeatability of the Lenstar biometer used in our study. One of these studies is concerned with intrasession repeatability,[9] which is irrelevant as the appropriate comparison for a study involving combinations of conditions investigated at different times is intersession repeatability. Shammas and Hoffer[10] found repeatability as given by the standard deviations of intersession differences of 0.10 mm. While this is of the order of our largest effects, the sessions were conducted 1 month apart rather than within a few days as in our study. It is interesting that the mean difference between sessions of 0.024 mm was nearly significant. A study which is a better comparison is that of Buckhurst et al.[11] with an intersession repeatability of 0.013 mm, much less than the effects we reported.

Relevant to the measurement variability issue is that our results were always in the direction supporting effect of gravity on anterior chamber depth, rather than sometimes in the opposite direction which might be expected if effects could be explained by measurement variability.

In summary, our study demonstrated that gravity has small, but real, effects on lens position during accommodation. It supported the Helmholtz theory that accommodation is produced by ciliary muscle contraction relaxing zonular tension and enabling the lens to reduce in diameter and take up a more rounded form. It provided evidence against Schachar's alternative theory of accommodation that ciliary muscle contraction increases zonular tension and increases lens diameter.

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