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Baseline pupil size is related to fluid intelligence: A reply to Unsworth et al. (2021)

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We have repeatedly shown that baseline pupil size is related to fluid intelligence (Heitz et al., 2008; Tsukahara & Engle, 2021; Tsukahara et al., 2016) and that this relationship is robust to a number of potential confounding factors such as differences in mental effort, initial exposure to a new environment, nicotine use, medical drug use, age, and race (Tsukahara et al., 2016). More recently, we demonstrated across two large-scale studies that when baseline pupil size is measured in bright lighting conditions all subjects display small pupils—that is, there is little variability in baseline pupil size between subjects (Tsukahara & Engle, 2021). Because of this, baseline pupil size did not correlate with fluid intelligence in our brightest lighting conditions but it did when measured in moderate to dark lighting conditions. Additionally, across all of our studies, we have shown that baseline pupil size is uniquely related to fluid intelligence, not working memory capacity (Tsukahara et al., 2016; Tsukahara & Engle, 2021).

In a commentary to our findings in Tsukahara and Engle (2021), Unsworth et al. (2021) argued that there is no relationship between baseline pupil size and cognitive ability, and that when such a relationship is found it can be wholly explained by confounding variables—namely age and racial differences. Their claims ignore our previous study, Tsukahara et al. (2016), that had a relatively broad sample in terms of race and cognitive ability, in which we found that age and racial differences could not explain the relationship between baseline pupil size and fluid intelligence (see Fig. 1). Therefore, their argument fails to consider Tsukahara et al. (2016) and instead focuses on Tsukahara and Engle (2021), which had a notably larger imbalance between racial groups. In fact, if we combine the data from all three studies ($N = 831$), fluid intelligence does predict baseline pupil size even after controlling for age and race; $b = 0.13$ [0.04–0.22], $p < .05$.

Conducting individual differences research requires recruiting a broad and representative sample; an objective that we spend a considerable amount of effort and resources to achieve in our studies. In doing so, this means there will be diversity among various demographic variables such as age, gender, race, and socioeconomic status. The nature of individual differences research is such that it is not possible to achieve a perfectly balanced sample across *all* demographics. Therefore, caution needs to be exercised when interpreting the confounding effects of demographic variables; especially when they are *strongly* correlated with the variables of interest. Unsworth et al. have, repeatedly, thrown this caution out the window when they argued that age (2019) and now racial differences (2021) can wholly explain the relationship between baseline pupil size and fluid intelligence. We cannot find a scientifically justified reason that pupil size would depend on race, except for covarying factors, namely that racial minorities experience systematic inequalities resulting in lower socioeconomic status (Ryan & Siebens, 2012), stereotype threat (Steele & Aronson, 1995), and test hesitancy (Chan et al., 1997), and therefore, tend to perform worse on cognitive measures (Roth et al., 2001). Potential race differences in cognitive performance is an important societal problem which requires attention and remediation, however such differences do not invalidate our findings on baseline pupil size and fluid intelligence.

In Tsukahara and Engle (2021), we provided compelling evidence that the primary reasons other researchers have failed to find the baseline pupil size-cognitive ability relationship is that 1) their lighting conditions did not allow sufficient variability in baseline pupil size between individuals and 2) they measured working memory capacity and not fluid intelligence. There are other factors that have led researchers to not find a significant correlation between baseline pupil size and cognitive ability (Unsworth et al., 2020) including small sample sizes ($n < 200$), an ability restricted sample, a non-diverse sample, and using

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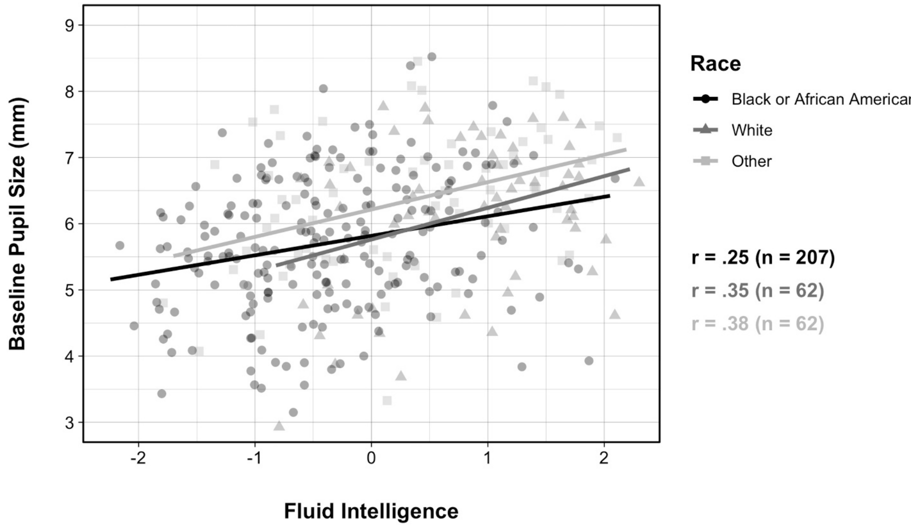

Fig. 1. Correlation between baseline pupil size and fluid intelligence (z-scored) for Black or African American, White, and Other. Within each racial group, there was a correlation between baseline pupil size and fluid intelligence and that correlation was not statistically different between groups (Fig. 1). Furthermore, when both age and race are added as covariates, baseline pupil size still correlated with fluid intelligence. Figure adapted from Tsukahara et al. (2016).

only a single task to measure working memory capacity or fluid intelligence. We encourage researchers investigating the relationship between baseline pupil size and cognitive ability to heed our recommendations in Tsukahara and Engle (2021), as well as to focus on fluid intelligence and not working memory capacity.

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