speed and display time. Some require specific head movement and changing targets (inVisionTM device) while others fixed head position (DinVA 3.0 softwear 0).[1]

The Dyop Chart2020 (Konan Medical,Hyogo, Japan) device may be falsely categorized as measuring DVA and therefore we shall elaborate. Though the visual target is dynamic, this method measures SVA as the target remains stationary in three dimensional space. It rotates around itself, projected consistently on the same (central fixation) retinal area, requiring no head or eye movement.[8] Projected on a computer monitor, the target is comprised of a dynamically sized ring containing black and white segments of a calculated angle and area uniformly spinning on a neutral grey background. The endpoint acuity is the threshold when the rotation appears to stop. Acknowledging that changes in stimulus provokes an excitatory response from photoreceptors, this kinetic target more closely complements the visual response than a static target, requiring small eye movements to refresh photoreceptors.[8] The ease of interpretation is an advantage where patients are less communicative, or illiterate. A correlation between the Dyop to Sloan and LogMAR E charts has been determined.[8]

Head mounted virtual reality (VR) devices are becoming more commonplace and may be programmed for DVA measurement.[9] The nature of the apparatus allows the observer to move and experience moving targets more closely to a natural environment on the z axis, including the peripheral field unlike previous devices such as targets on a static computer screen, measuring KVA as well. Though image resolution continuously improves, the inferiority of VR devices compared to the retina can cause a discrepancy between the VOR and visual system. Excess display time of the image on a retinal area can result in an after-image, prejudicing results for example by allowing for a longer interpretation time. Researchers are still trying to understand the influence of the immersive medium on other systems such as accommodation and convergence.[10] But advances in technology and their allowance for precise control over multiple target parameters regardless of head movement is encouraging that exploration in this area may produce a structured model of norms and acquisition protocol.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Estimating the prevalence of heterochromia iridum from high-resolution digital yearbook portraits

Introduction

Heterochromia iridum (HI), or complete heterochromia, is a condition where an individual's irises are of two different colors.[1] It may be congenital, with or without a syndromic relationship, or acquired through injury, medication, or other means.[2] Immaterial of its origin, HI is generally thought to be harmless and easily diagnosable. For these reasons, HI receives little attention in the medical literature, especially when it is not associated with a more concerning medical condition or cause. For example, a PubMed search on June 19, 2021 returned just 16 results for HI and complete heterochromia among its 32 million citations, and all 16 articles headlined HI's relationship with a syndrome, abnormality, or disease.[3] Not surprisingly, a precise measure of HI's prevalence remains an open question, although it is considered rare.

While it is possible HI is benign and presents no real medical risk, its association with troubling underlying medical conditions “warrants investigation".[4] Moreover, it is difficult (if not impossible) to study potential correlations between HI and other more serious diseases without a better understanding of its prevalence. To the best of our knowledge, the most expansive attempt at estimating HI’s prevalence was undertaken by Stelzer, who personally examined over 25,000 Viennese people between 1 and 80 years old in the late 1960s.[5] Notably, he only considered cases without a presumed pathological cause, and he reported an observed prevalence of 0.06313%.[5]

Material and methods

To augment the limited body of knowledge on HI’s prevalence, we estimate it using a collection of high-resolution digital yearbook portraits of United States Military Academy (USMA) cadets. As a secondary analysis of publicly available, subsequently deidentified data, USMA’s Institutional Review Board determined this research met 32 CFR § 219.104′s requirements for exempt status.[6]

Demographically, our sample’s subjects have homes of record that abide the geospatial distribution of US congressional seats, and they are generally between 20 and 26 years old. They are also healthy. Specifically, the US Department of Defense Medical Examination Review Board medically screens cadets prior to entering USMA. This extensive process includes an eye examination. After admission, cadets receive periodic health assessments throughout their tenure at USMA, and a significant injury or change in health can trigger medical separation. Finally, eye color tends to stabilize by 6 years of age with minimal changes up to early adulthood.[7] Taken together, HI cases in our sample are likely congenital, unassociated with other diseases, and perpetual.

Procedurally, the study followed four steps: (1) photo preparation, where the eyes were identified and extracted from each image using a modern machine learning approach; (2) preliminary identification, where non-experts flagged possible cases; (3) final determination, where an optometrist confirmed or denied the possible cases; and (4) statistical analysis, where prevalence was estimated.

While Steps (2) through (4) are self-explanatory, Step (1) merits additional discussion. Specifically, our algorithm applies Zhang et al.’s Multitask Cascaded Convolutional Networks model, which takes a photo as an input and outputs a set of coordinates representing five facial landmarks, including the eyes.[8] For each photo’s eye coordinates, we subsequently crop the image twice – once for the left eye and once for the right eye, where each cropped image is a square centered on the respective eye’s coordinates. Based on the standard composition of the yearbook portraits, the square’s side length was easily tuned to a constant that ensured the iris was contained in each cropped image, and these ocular photos were subsequently arranged in subject pairs. Step (1) was automated using the Python programming language, allowing us to focus our manual efforts on HI identification.

Results

Ultimately, 11,111 photos were processed, and 7 cases of HI were confirmed for an observed prevalence of 0.06300%. Based on its small value, we quantified the uncertainty of our estimate with a 95% Agresti-Coull confidence interval (CI)[9] built using R’s binom package,[10] which yielded (0.02761%, 0.13291%). Our point estimate is nearly identical to Stelzer’s result, and our CI contains it. Based on the latter, we fail to reject the null hypothesis of their equality at a significance level of 0.05. That said, it is possible we missed subtle cases in Step (2); therefore, our estimate is potentially conservative.

Discussion

Previously, the most ambitious attempt at estimating HI’s prevalence was Stelzer’s.[5] Despite being the largest such study, it is over 50 years old, drawn exclusively from Vienna residents, and includes young children whose eye color was potentially still developing. Our work affirms Stelzer’s result using a geographically diverse, certifiably healthy sample of young adults with more stable iris coloration. This finding is important to the future study of HI, including possible associations between HI and more serious underlying conditions. Additionally, this study creates the opportunity to extend the machine learning methodology to classify HI from images. Such work could be expanded beyond HI to detect other visible eye disorders.

Disclaimer

The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Declaration of Competing Interest

None.

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