Available online at www.sciencedirect.com
ScienceDirect
Vision Research 47 (2007) 2179–2186
Vision Research
www.elsevier.com/locate/visres

Genetic influence on contrast sensitivity in middle-aged male twins

Alice Cronin-Golomb [a,*], Matthew S. Panizzon [a], Michael J. Lyons [a], Carol E. Franz [b], Michael D. Grant [a], Kristen C. Jacobson [c], Seth A. Eisen [d,e], Thomas M. Laudate [a], William S. Kremen [b,f]

[a] *Department of Psychology, Boston University, 648 Beacon St., 2nd floor, Boston, MA 02215, USA*
[b] *Department of Psychiatry, University of California, San Diego, La Jolla, CA, USA*
[c] *Department of Psychiatry, University of Chicago, Chicago, IL, USA*
[d] *Department of Veterans Affairs, Washington University School of Medicine, St. Louis, MO, USA*
[e] *Department of Psychiatry, Washington University School of Medicine, St. Louis, MO, USA*
[f] *Center for Behavioral Genomics, University of California, San Diego, La Jolla, CA, USA*

Received 11 September 2006; received in revised form 3 April 2007

Abstract

Contrast sensitivity is strongly associated with daily functioning among older adults, but the genetic and environmental contributions to this ability are unknown. Using the classical twin method, we addressed this issue by examining contrast sensitivity at five spatial frequencies (1.5–18 cycles per degree) in 718 middle-aged male twins from the Vietnam Era Twin Study of Aging (VETSA). Heritability estimates were modest (14–38%), whereas individual-specific environmental influences accounted for 62–86% of the variance. Identifying the types of individual-specific events that impact contrast sensitivity may suggest interventions to modulate this ability and thereby improve overall quality of life as adults age.

Keywords: Spatial; Contrast; Aging

1. Introduction

Basic visual abilities such as acuity, contrast sensitivity, motion detection, color discrimination, and depth perception are all affected by aging, but the sources of variability in visual status across older individuals are as yet incompletely understood. Increasingly, it is recognized that deficits in basic visual abilities contribute significantly to impairments in higher cognitive processes and activities of daily living. This relation between vision, cognition, and daily function has been reported in healthy older adults (Ball & Sekuler, 1986; Gilmore, Spinks, & Thomas, 2006; Gilmore, Thomas, Klitz, Persanyi, & Tomsak, 1996; Owsley, Sekuler, & Boldt, 1981) as well as in individuals with age-related neurodegenerative disorders, such as Alzheimer's disease (Cronin-Golomb, Corkin, & Growdon, 1995; Dunne, Neargarder, Cipolloni, & Cronin-Golomb, 2004; Gilmore, Cronin-Golomb, Neargarder, & Morrison, 2005; Gilmore et al., 1996; Gilmore et al., 2006) and Parkinson's disease (Amick, Cronin-Golomb, & Gilmore, 2003; Davidsdottir, Cronin-Golomb, & Lee, 2005). As the population ages it becomes more important to determine the sources of variation in visual abilities in order to permit the development of visual interventions that may improve cognition and daily function. In particular, determination of the relative contributions of genetic and environmental influences on visual ability may be especially enlightening.

Spatial frequency contrast sensitivity is one of the most studied visual abilities, in part because of its association with deficits in daily function in older adults (e.g., Cormack, Tovee, & Ballard, 2000; Dargent-Molina, Hayes, & Bréart, 1996; Dunne et al., 2004; Elliot, Bullimore, Patla, & Whitaker, 1996; Elliott, Hurst, & Weatherill, 1990; Lord,

* Corresponding author. Fax: +1 617 358 1380.
E-mail address: alicecg@bu.edu (A. Cronin-Golomb).

0042-6989/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.visres.2007.04.017

Clark, & Webster, 1991a, 1991b). It has been reported that up to 57% of the variance in performance of activities of daily living (ADLs) in older adults is attributable to variability in acuity and contrast sensitivity (West et al., 2002). One study indicated that a twofold reduction in contrast sensitivity resulted in a three- to fivefold increase of difficulty with ADLs (Rubin et al., 2001). Deficient contrast sensitivity may arise from dysfunction at multiple points along the visual pathways, from the lens and retina to primary visual cortex and higher cortical areas (reviewed in Cronin-Golomb & Gilmore, 2003; Matjucha & Katz, 1994; Spear, 1993).

In normal aging, changes in contrast sensitivity are well established for higher spatial frequencies. High-frequency loss is common in normal aging owing in part to changes in the lens and other anterior structures but mainly to neural factors, such as changes in the retina or central visual pathways (Matjucha & Katz, 1994; Owsley, Gardner, Sekuler, & Lieberman, 1985; Owsley, Sekuler, & Siemsen, 1983; Spear, 1993). In a study stratifying by age (Owsley et al., 1983), it was found that age had no effect on static contrast sensitivity at the lower frequencies of 0.5 and 1.0 cpd, but sensitivity decreased at higher frequencies (2.0–16.0 cpd) beginning at about 40–50 years of age. Given the evidence for genetic influence on other factors that show age-related change (see Bergeman, 1997; Finkel, Pedersen, Berg, & Johansson, 2000; Pedersen, 1996, for reviews), it is possible that genetic factors may also play a role in contrast sensitivity. The finding that age-related declines in contrast sensitivity are not seen at all spatial frequencies suggests that there may be different mechanisms involved, and that the importance of genetic and environmental factors may vary for different frequencies.

To our knowledge, there are no published data that address the relative influence of genetic and environmental influence on variation in contrast sensitivity. However, a number of disorders with a strong genetic component are also associated with contrast sensitivity loss at some or most spatial frequencies, including Alzheimer's disease, especially at the lower frequencies (Cronin-Golomb et al., 1991; Cronin-Golomb et al., 2000; Mendola, Cronin-Golomb, Corkin, & Growdon, 1995) and optic neuritis of various etiologies, especially for the middle range of frequencies (Ashworth, Aspinall, & Mitchell, 1989; Wright, Drasdo, & Harding, 1987). If there is evidence of genetic influence on contrast sensitivity, this could indicate that contrast sensitivity may be considered a possible endophenotype for these disorders (Gottesman & Gould, 2003). Alternatively, genes causing these disorders might have a direct influence on contrast sensitivity (e.g., as a result of visual cortex atrophy). The mechanisms through which the same or different genes may affect such disorders as well as contrast sensitivity can be determined by multivariate genetic analyses, but such analyses must await basic studies of genetic and environmental influences on contrast sensitivity itself.

In the present study, we used the twin method to examine the heritability of visual spatial frequency contrast sensitivity in a large cohort of middle-aged men from the first wave of the longitudinal Vietnam Era Twin Study of Aging (VETSA). The twin method allows the estimation of the relative influences of genes and environment on a particular trait or ability, such as contrast sensitivity. Because monozygotic (MZ) twins share all of their genes whereas dizygotic (DZ) twins, like other siblings, share on average 50% of their genes, the greater the difference is in the degree of similarity within MZ twin pairs compared to DZ pairs, the stronger the genetic influence is on those abilities. By examining the importance of genetic and environmental influences on contrast sensitivity in a middle-aged sample that we are following over time, we begin the first step in understanding the mechanisms that are responsible for both age-related changes in contrast sensitivity and its subsequent effect on the overall quality of life among older adults. In order to place the results from our middle-aged sample in the context of aging, we also show the mean contrast sensitivity at each frequency from data that we have collected in another study of younger and older adults.

2. Methods

2.1. Description of the Vietnam Era Twin Study of Aging (VETSA)

Data collection began in 2003 for the longitudinal Vietnam Era Twin Study of Aging (VETSA). Study participants are from the Vietnam Era Twin (VET) Registry, a population-based sample of male–male twin pairs living throughout the United States. Registry members were born between 1939 and 1957, served in the military from 1965 to 1975, and are representative of all veterans from the Vietnam War era on a variety of sociodemographic variables (Eisen, True, Goldberg, Henderson, & Robinette, 1987; Goldberg, True, Eisen, Henderson, & Robinette, 1987). In the early 1990s, 3322 VET Registry twin pairs participated in the Harvard Twin Study of Drug Abuse and Dependence, a telephone survey of lifetime substance use and psychopathology (Tsuang, Bar, Harley, & Lyons, 2001). Zygosity was determined by a combination of questionnaire and blood group typing, an approach that has been demonstrated to be 95% accurate (Eisen, Neuman, Goldberg, Rice, & True, 1989). Participants in the present study were randomly selected from those twin pairs who had participated in the Harvard Twin Study of Drug Abuse and Dependence.

2.2. Sample

2.2.1. VETSA twin sample

This report is based on the first 746 individuals who participated in VETSA. Twins were given the option of traveling to Boston University or the University of California, San Diego, for a day-long series of physical and cognitive assessments. Approximately equal numbers were studied at each site and 26 participants were tested off-site, with examiners traveling to their home towns. The present analyses include data from 718 participants for whom standard equipment and chart illumination were available: 185 complete MZ pairs and 155 complete DZ pairs, as well as data from 15 unpaired MZ twins and 23 unpaired DZ twins. We did not administer the contrast sensitivity test to 28 of the 746 participants; only two on-site participants did not take the test, but the test was not available for those who participated off-site. The study was undertaken with the understanding and written consent of each participant. All participants were in their 50s at the time of recruitment, two of whom were 60 by the time of the assessment. The mean level of education was 13.9 ± 2.1 years (range 4–20).