

# **Grapheme-Color Synesthesia is Associated with PTSD**

CES: Combat Experience Scale; DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; GC: Geisinger Clinic; PTSD: Post-traumatic Stress Disorder

Synesthesia represents a phenomenon in which sensations arise in an unrelated sense modality upon presentation with one sensory modality (Brang & Ramachandran, 2011). Previous studies suggest that synesthesia is prevalent at the rate of about 3-4% among the general population (Asher et al., 2009) with an increased prevalence in first-degree relatives (Baron-Cohen, Burt, Smith-Laittan, Harrison, & Bolton, 1996). Grapheme-color synesthesia is the most common form of synesthesia (Simner & Carmichael, 2015), whereby a number or a letter elicits a concurrent image or a specific color perception (Niccolai, Jennes, Stoerig, & Van Leeuwen, 2012).

Synesthesia may be a marker for underlying neurophysiologic and neuroanatomic changes resulting in cross activation of brain maps (Ramachandran & Hubbard, 2001). Recently it has been suggested that certain mechanisms associated with synesthesia and associated processes may reflect psychopathological symptoms related to enhanced temporo-limbic excitability (Neckar & Bob, 2016). Since brain activity during synesthetic color experiences appears to develop from within the ventral temporal lobe, it has been proposed that the phenomenon of grapheme-color synesthesia manifests from abnormal cross-wiring or feedback between different regions of the brain engaged in extracting visual characteristics of form and color (Mattingley, 2009), although this hypothesis has been questioned (Hupe & Dojat, 2015).

Synesthesia has also been linked to some medical conditions, such as irritable bowel syndrome (IBS), migraine headache, and Asperger syndrome (Alstadhaug & Benjaminsen, 2010;

Carruthers, Miller, Tarriner, & Whorwell, 2012; Neufeld et al., 2013). Individuals with synesthesia also appear to have particular personality traits (Hoffman et al., 2018; Rouw & Scholte, 2016), but further systematic research is required to validate this association.

Nevertheless, synesthesia may confer a benefit to some individuals, noting that synesthetes are more commonly engaged in the arts and that increased creativity has been associated with grapheme- and sound-color synesthesia (Lunke & Meier, 2018). Heightened associative learning (Bankieris & Aslin, 2016) and enhanced visual memory have been found in grapheme-color synesthetes, particularly for visual recognition tasks.

recruited for an even larger study pertaining to the evaluation of health effect of military service. All the veterans in the study population were outpatients in the Geisinger Clinic (GC), which is one of the largest multi-hospital systems in Pennsylvania (Boscarino et al., 2016). Based upon the medical record numbers,

current life stress, traumatic stress exposure, combat exposure, depression, and history of concussion using a backwards stepwise logistic regression (Table 2). Data analyses were conducted using Stata, version 13.1 software (College Station, Texas). This study was approved by the Institutional Review Boards of the Geisinger Clinic and US Department of Defense.

In the present study, examination of the recruited veterans revealed that 56.2% were Vietnam veterans, 15.9% belonged to Gulf War, 22.9% were veterans of Afghanistan/Iraq, and the rest (14.2%) represented other warzone veterans (Table 1, footnote). As shown in Table 1, the average age of veterans was 59.6 years among which, 95.1% were males, while 95.7% belonged to White race. Also, 77.5% were married, 24.8% had an educational level equivalent to college graduate or higher education and 23.6% of the study group was categorized as having high combat exposure. A total of 28.4% of veterans were screened positive for concussive injury during military service and 22.2% reported taking psychotropic medications in the past year. In the present study, the prevalence rate of current PTSD was about 7.6% (95% C.I. = 6.5-9.0) and the prevalence rate of current depression was found to be about 8.3% (95% C.I. = 7.1-9.7). Among the veterans of the current study, the prevalence of grapheme-color synesthesia was 3.4% (95% C.I. = 2.7-4.4) (Table 1).

The top row in Table 2 shows the unadjusted bivariate results for the association between PTSD and synesthesia. It is evident that the unadjusted odds ratio (OR) for the association between

the rate observed in previous studies of community-based veterans (Boscarino et al., 2015). Finally, both PTSD and synesthesia are known to be associated with genetics and these need to be further explored (Boscarino et al., 2012; Brang & Ramachandran, 2011).

In spite of these limitations, grapheme-color synesthesia was found to be associated with PTSD in a second larger community-based group of veterans. It is suspected that the PTSD-synesthesia association is probably not specific to combat trauma per se, but may likely be related to noncombat traumas as well. Among these veterans, it is a notable fact that the median age of PTSD onset was 28 years (Hoffman et al., 2012). As evident from Table 1, the average age of veterans in the present study was 59 years, therefore most veterans had PTSD for decades. Recognition of the association between synesthesia and PTSD might lead to new approaches for PTSD diagnosis, such as using the “New York PTSD risk score,” which combines psychosocial risk-factor data with genotype data (Boscarino, Kirchner, Hoffman, & Erlich, 2013). Further longitudinal research is planned to explore these

Brang, D., & Ramachandran, V.S. (2011). Survival of the synesthesia gene: Why do people hear colors and taste words? *PLoS Biol*, 9(11): e1001205.