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Endogenous testosterone levels, mental rotation performance, and constituent abilities in middle-to-older aged men

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Abstract

Evidence from both human and animal studies suggests that gonadal steroids, such as testosterone, exert activational effects on adult spatial behavior. Endogenous testosterone levels decline gradually but variably as men age; it remains to be shown whether these decreases are associated with age-related declines in visuo-spatial performance or constituent abilities indicative of generalized age-related cognitive decline. Ninety-six healthy, community dwelling men aged between 38 and 69 years completed the Vandenberg and Kuse Mental Rotation Test (MRT) together with a battery of tests including processing speed, executive function, perceptual discrimination, working memory, and reaction time measures. Significant main effects of tertiles of calculated free testosterone levels (cEFT) were found on composite measures of processing speed, executive function, and perceptual discrimination ability in a subset of men aged over 50 years in age and crystallized intelligence controlled analyses; higher cEFT levels were associated with poorer performance. Hierarchical multiple regression and path analyses on the whole data set showed that cEFT levels negatively moderated processing speed performance, which in turn predicted both working memory and MRT performance with aging. Together these data suggest that age-related declines in endogenous testosterone levels in healthy middle-to-older aged men are not associated with generalized age-related cognitive decline.

Keywords: Testosterone; Mental rotation; Males; Aging; Processing speed; Executive function

Introduction

Testosterone (T) supplementation studies in older males have demonstrated that increasing circulating T levels improves performance on tests of spatial ability (Cherrier et al., 2001, 2004, 2005, 2007; Janowsky et al., 1994). These data suggest that androgens have activational effects which facilitate spatial behavior in males and that these effects are most evident in older men. It remains to be determined, however, whether age-related declines in circulating T levels are associated with poorer performance on tests of spatial ability as males age or whether these changes are associated with generalized age-related cognitive decline.

There is evidence from animal studies (Williams et al., 1990; Williams and Meck, 1991; Isgor and Sengelaub, 1998) and studies in humans (Imperato-McGinley et al., 1991; Masica et al., 1969) that androgens exert early organizational effects on spatial ability which, in turn, affect adult performance. Furthermore, evidence from studies in animals suggests that the activational effects of T may also facilitate spatial abilities in adult males (Daniel et al., 2003; Kritzer et al., 2001; Sandstrom et al., 2006). Some correlational studies with younger men (Errico et al., 1992; Hooven et al., 2004; Silverman et al., 1999) and supplementation studies in older men (Cherrier et al., 2001, 2004, 2005, 2007; Janowsky et al., 1994) support this hypothesis; however, the results are far from consistent, with many studies finding either negative associations (e.g., Yonker et al., 2006; Gouchie and Kimura, 1991; Moffat and Hampson, 1996) or no relationship at all (e.g., Fonda et al., 2005; Kempel et al., 2005; Falter et al., 2006; McKeever et al., 1987). Factors which may account for

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these discrepancies between studies include: the age of the male participants; the use of heterogenous tests of visuo-spatial ability; the confounding influence of T's organizational effects on brain lateralization and sexuality; the influence of health and lifestyle variables on both T levels and cognition; and differences in T measurement and determination.

The Vandenberg and Kuse Mental Rotation Test (MRT; Vandenberg and Kuse, 1978) exhibits the largest and most robust of all sex differences in cognitive abilities. According to two large meta-analytic reviews the gender difference is between $d=0.76–0.94$, that is, in the vicinity of 1 SD (Voyer et al., 1995; Linn and Petersen, 1986). This difference is robust with aging (Halpern, 2000; Salthouse, 1998) and cannot be accounted for by either socialization or environmental factors (e.g., computer game experience; Quaiser Pohl et al., 2006; Terlecki and Newcombe, 2005: gender role socialization; Saucier et al., 2002; Voyer et al., 2000) or performance factors, such as time limits or scoring procedures (Peters, 2005; Masters, 1998).

While previous studies on T and MRT performance have tended to use young university aged males (e.g., Hooven et al., 2004; Falter et al., 2006; Kempel et al., 2005; Gouchie and Kimura, 1991; Silverman et al., 1999), very little data exist on the association between plasma T and MRT performance as men age. Wolf and Kirschbaum (2002) found no relationship between either T or free testosterone (FT) and mental rotation performance in a study involving 30 healthy elderly men (aged: 69.0±1.3). Similarly, a T supplementation study involving 17 healthy elderly males (aged: 68.7±1.9) found no statistically significant improvement on the same test of mental rotation, although T levels were increased to three times those of a young control group (Wolf et al., 2000). It is important to note, however, that both of these studies involved relatively small samples of elderly men (i.e., Wolf and Kirschbaum (2002), $N=30$; Wolf et al. (2000), $N=17$) and a test of mental rotation (Horn, 1983) which involved letters and numbers instead of the 3D geometric figures used in the Vandenberg and Kuse MRT. Importantly, no study to date has specifically examined associations between T and MRT performance in healthy middle-to-older aged males while controlling for confounds known to affect both T and cognition.

Research into associations between T and cognitive function, particularly in older and elderly men, has similarly generated equivocal results across a broad spectrum of both cognitive and neuropsychological tests. In general, these studies have employed a variety of cognitive ability measures (e.g., verbal memory, working memory, processing speed, and executive function) to determine whether higher T levels in older males are neuroprotective, and several have reported positive associations between both T and processing speed (Martin et al., 2007a; Hogervorst et al., 2004; Yaffe et al., 2002; Muller et al., 2005) and between T and executive function (Barrett-Connor et al., 1999; Muller et al., 2005; Perry et al., 2001). These associations are of particular interest because of theories that relate processing speed (e.g., Salthouse, 1996a) and executive function (e.g., West, 1996) to generalized age-related cognitive decline.

An investigation into the relationship between T and the cognitive processes underlying MRT performance recently concluded that, although T levels in males are not directly associated with the slopes of the rotation functions, T may facilitate MRT performance through its effect on underlying cognitive processes (Hooven et al., 2004).

To determine, firstly, whether T levels were directly associated with performance on the Vandenberg and Kuse MRT; second, whether T may facilitate MRT performance by modulating abilities constituent to task performance; and, third, whether changes in T levels with aging were associated with generalized age-related cognitive decline, we administered a number of different tests of processing speed, executive function, and working memory (WM) to a healthy sample of middle-to-older aged males. To help elucidate these associations, strict exclusion criteria were imposed to control for confounds related to the organizational effects of gonadal steroids on spatial performance (i.e., handedness, sexuality), health and disease factors known to affect hormone levels and/or cognition, and other factors negatively related to cognitive performance.

Method

Participants

Participants ($N=96$) were recruited from the 1195 men aged 35–80 years participating in the Florey Adelaide Male Ageing Study (FAMAS), a large cross-sectional study of the community dwelling population of males in Adelaide's northern and western suburbs. Participants were recruited to form three age groups: 38–49 years ($N=29$), 50–59 years ($N=37$), and 60–69 years ($N=30$).

Selection and exclusion criteria

We included only right-handed, exclusively heterosexual men, without any self-reported history of anxiety, depression, diabetes, thyroid problems, or prostate cancer, and with an average daily alcohol consumption of below 40 g per day. This information was obtained from the FAMAS database. Men were excluded if they were currently taking hormone supplements or medication likely to affect mental performance, had a history of psychiatric illness or drug abuse, suffered from a neuropsychological condition, or had recently suffered a head injury. This information was based on self-report (see Martin et al., 2007b).

Materials and apparatus

Questionnaires

Alcohol intake: Participant's daily alcohol intake was calculated (in grams) from information obtained using the Australian Cancer Council of Victoria's (ACCV) electronically scored dietary questionnaire.

Handedness questionnaire: An English translation of The Dutch Handedness Questionnaire (Van Strien, 2002) was used as a measure of handedness. The questionnaire consists of 10 questions which are scored +1 for 'right', 0 for 'both', and −1 for 'left'. Scores vary from −10 for extremely left-handed to +10 for extremely right-handed.

Cognitive tests

Mental rotation test. The Vandenberg and Kuse Mental Rotation Test: We used a computerized version of the Vandenberg and Kuse (1978) MRT, which measures three-dimensional mental rotation ability. Each question consisted of a target drawing and four test drawings. Participants were required to designate which two of the four test drawings correctly depicted the target drawing in rotated positions. To select an item, participants were required to use the computer mouse to click numbered boxes displayed under each alternative. To answer each question, participants had to select two items then click a button displayed at the bottom of the screen to finalize the response. Alternatively, participants could skip the question by selecting no items and clicking the button