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The relationship between sex steroid hormones and behavioural inhibition (BIS) and behavioural activation (BAS) in adolescent boys and girls

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ABSTRACT

This paper analyses the association between free testosterone (FT), free estradiol (FE2) and Carver and White's (1994) four-factor model of behavioural inhibition (BIS) and behavioural activation (BAS) within a sample of adolescent boys (N = 301, mean age: 14.4 years) and girls (N = 298, mean age: 14.3 years). No direct relationship between FT and BIS or BAS was found in either boys or girls. An association between FE2 and BAS-fun was found in boys and in girls. In addition, with respect to girls, interaction-effects were found indicating a positive association between FE2 and BAS-drive and a negative association between FT and BAS-fun depending on menstrual cycle phase.

1. Introduction

Several studies have suggested that a relationship exists between fluctuating levels of sex steroid hormones and forms of behaviour like adolescent risk-taking or delinquency. Research has focussed primarily on the association between adolescent risk-taking and testosterone—the hormone that masculinises the body in utero and at puberty—(Booth, Johnson, Granger, Crouter, & McHale, 2003; Rowe, Maughan, Worthman, Costello, & Angold, 2004; Vermeersch, T'Sjoen, Kaufman, & Vincke, 2008a). In addition some evidence exists of an association with estradiol (Paikoff, Brooks-Gunn, & Warren, 1991; Vermeersch, T'Sjoen, Kaufman, & Vincke, 2008b)—the hormone that is more abundant in females and that plays a role in reproduction, sexual function and motivation. However, so far, the motivational mechanisms that may be important in understanding the association between sex steroids and behaviour have remained a "black box".

Two broadband motivational systems, behavioural inhibition (BIS) and behavioural activation (BAS), conceptualised by Gray in his neurobiological reinforcement sensitivity theory (1972), are possible candidates for mediating the association between sex steroids and behaviour. In Gray's original conceptualisation, the BIS system may influence behaviour by regulating the sensitivity to conditioned signals of punishment and frustrative non-reward that forms the basis of differences in anxiety proneness (Gray, 1994) and, more generally, negative affect and state anxiety. The BAS system is relevant to behaviour because it influences sensitivity to conditioned signals of reward and relief from punishment, regulates appetitive motivation, forms the basis of impulsivity (Gray, 1994), and is conceptually related to Zuckerman's sensation seeking (1979).

Gray and McNaughton (2000) have, more recently, revised several aspects of the theory. While debate continues on several aspects, e.g., the independence of BIS and BAS, the status of the fight/flight system (for an overview, see Corr (2008) and Smillie, Pickering, and Jackson (2006)), a relative consensus exists that reward and punishment sensitivity are related to various forms of behaviour, mood and cognition (Johnson, Turner, & Iwata, 2003). If BIS and BAS are related to sex steroid hormones they may help to explain part of the associations between hormones and forms of behaviour like, e.g., risk-taking.

Research on the relationship between sex steroid hormones and personality concepts within the BIS and/or BAS domain has remained scarce. There is mixed evidence regarding the relationship between testosterone and BAS-related concepts such as sensation or novelty seeking. Daitzman, Zuckerman, Sammelwitz, and Ganjam (1978) and others (Aluja & Torrubia, 2004; Galligani, Renck, & Hansen, 1996; Gerra et al., 1999) found at least some evidence of that relationship, although results have been gender specific (Kerschbaum, Ruemer, Weishuhn, & Klimesch, 2006) and were not always replicated (Daitzman & Zuckerman, 1980; Rosenblitt, Soler, Johnson, & Quadagno, 2001; Wang et al., 1997). While studies have shown that testosterone may have anti-depressant and fear-reducing properties (Hermans, Putman, Bass, Koppeschaar, & van Honk, 2006), this does not necessarily imply that an association exists between testosterone and BIS (Van Honk, Peper, & Schutter, 2005).

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While less studied, estradiol may also be relevant with respect to BIS- and BAS-related concepts. Several small studies have provided evidence of an association between E2 and sensation seeking in girls (Daitzman & Zuckerman, 1980; Daitzman et al., 1978) although the results were not always consistent: Balada, Torrubia, and Arque (1993) have found a negative association between estradiol and thrill- and adventure-seeking while Aluja and Torrubia (2004) have found a positive, but not significant, association between estradiol and sensation seeking. In boys, estradiol is directly derived from testosterone through the enzyme aromatase (Finkelstein et al., 1997). Finkelstein et al. (1997) hypothesise that – through aromatase – estradiol rather than testosterone may be the more proximal factor in the etiology of aggressive behaviour. Few studies have addressed the relationship between testosterone and estradiol on behaviour and/or motivation simultaneously and it remains unknown whether this hypothesis may be relevant to behavioural or motivational concepts other than aggression, e.g., BIS/BAS.

In a recent publication, we reported associations between adolescent risk-taking and free testosterone in boys, while some but not all evidence suggested that this association could be due to free estradiol (Vermeersch et al., 2008a). In addition we found associations between adolescent risk-taking and estradiol but not testosterone in girls (Vermeersch et al., 2008b). Based on these results, we may expect to find, in the same sample of adolescents, associations between testosterone and/or estradiol and BIS and/or BAS in boys and between estradiol and BIS and/or BAS in girls.

2. Methods

2.1. Subjects

Data presented in this paper are part of ADORISK, a larger study on the social and biological determinants of the sex gap in adolescent risk-taking. The target group of this study was a population of third-grade students (14–15-year-old age group) selected within an educational setting. After an oral presentation on the goals of the study, informed consent letters were distributed to both students and their parents. In exchange for their participation, students were given an incentive. The Ethical Committee of the University Hospital of Ghent approved informed consent letters and privacy guarantees. Seventy-one percent of the eligible students participated, making up a total sample of 599 third-grade adolescents, 301 boys and 298 girls. The distribution of the girls in our sample across the different tracks of the Flemish educational system was relatively well-balanced compared with the distribution of the general third-grade population. More information on the sample is available in Vermeersch et al. (2008a, 2008b).

2.2. Operationalisation and measurement

2.2.1. Dependent variables

2.2.1.1. Hormone assays. Blood samples were collected by a nurse and were frozen at −80 °C while waiting for their assays. For girls, all blood samples were collected between 9:00 am and 12:00 pm As for boys, all blood samples were collected between 9:00 am and 11:30 am; 70.8% were collected before 10:00 am. An ANOVA analysis on boys showed no significant difference in total testosterone (TT), total estradiol (TE2) and SHBG (sex hormone-binding globulin) samples collected before and after 10:00 am.

Commercial immuno-assays were used to determine the serum concentrations of TT (Orion Diagnostica, Espoo, Finland), TE2 (Diasorin, Stillwater, MN, according to a modified protocol with the use of a double amount of serum), SHBG (Orion Diagnostica, Espoo, Finland). The assay sensitivity for TT was 10 ng/dl, the intra-assay coefficient of variation (CV) fell between 4.6% and 10.1%, and the inter-assay CV between 5.2% and 11.7%. The sensitivity for SHBG was 0.7 nmol/l, the intra-assay CV fell between 2.6% and 8.5%, and the inter-assay CV between 3.4% and 9.6%. The sensitivity for TE2 was 0.2 ng/dl, the intra-assay CV was 3%, and the inter-assay CV was 8.55%.

In our analyses, the unbound and, as such, bioactive forms of testosterone and estradiol—free testosterone (FT) and free estradiol (FE2)—are used rather than TT and TE2. FT and FE2 were calculated from the total serum hormone concentrations, serum SHBG and serum albumin by means of validated equations derived from the mass action law (Vermeulen, Verdonck, & Kaufman, 1999).

2.2.1.2. Questionnaire. Even though different instruments have been developed to assess BIS and BAS—and debate continues (Smillie et al., 2006) on the adaptation of existing scales to Gray and McNaughton's (2000) revised theory—the scales developed by Carver and White are frequently used and often validated (Carver & White, 1994; Franken, Muris, & Rassin, 2005; Jorm et al., 1999) tools. Carver and White's instruments consist of one inhibitory factor and three activational factors: (i) fun-seeking (BAS-fun), with items reflecting a desire for new rewards and a willingness to approach a potentially rewarding event on the spur of the moment; (ii) reward responsiveness (BAS-reward), with items that focus on positive responses to the occurrence or anticipation of reward; and (iii) drive (BAS-drive), consisting of items pertaining to the persistent pursuit of desired goals.

This paper used Franken et al.'s Dutch translation of these scales (Franken et al., 2005). Although the original scales presented only four possible answers—without the possibility of opting for "undecided"—a pretest of our questionnaire showed a rate of omissions up to 9.4%. For this reason, we provided five answer options. In our sample, Cronbach's Alpha for the BIS scale was 0.71 and for the BAS subscales was 0.72 (BAS-drive), 0.60 (BAS-reward), and 0.66 (BAS-fun). While the Cronbach's Alpha for BAS-reward was moderate, corrected item-total correlations for all scales were above 0.30.

2.2.2. Control variables

Age was referred to as years completed at the time of the research.

Pubertal development (PD) was measured by Tanner stage (1962) and assessed by a physician. Scores were assessed on the basis of pubic hair and breast development, both on a scale of 1 (prepubertal) to 5 (adult). Scores were totalled, resulting in an index of 2 through 10.

Girls using oral contraception were excluded from the analyses in accordance with Harris (1999).

The decision regarding whether or not to control for menstrual cycle-related variations in hormone levels was complicated as these variations are difficult to predict among young adolescent girls. Most research on hormones in adolescent girls does not control for hormonal cyclicity (e.g., Angold, Costello, Erkanli, & Worthman, 1999; Paikoff et al., 1991). Yet, a comparison of relationships at different phases of the menstrual cycle may result in a deeper understanding of why some studies find evidence for such a relationship and others not. For this reason, our study takes into account three phases of the menstrual cycle: (i) day 1 up to day 8 of the menstrual cycle, whose hormonal levels presumably reflect those of the early follicular phase, (ii) day 9 up to day 21 who presumably have increased estradiol and testosterone levels characteristic of the late follicular and early luteal phase, and (iii) day 22 up to day 35, whose hormonal levels more typically reflect those of the mid- to late-luteal phase. While the cut-off values of 8 and 21 appear arbitrary, day 8 is often regarded as the end of the early follicular phase and day 21 is the assumed day of ovula-